# MeshSLAM: Robust Localization and Large-Scale Mapping in Barren Terrain, Phase II

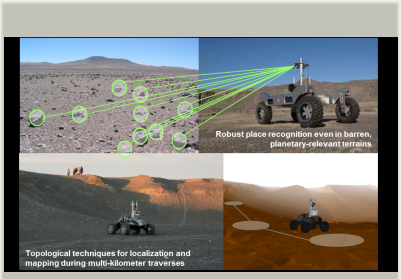
Completed Technology Project (2014 - 2016)

## Project Introduction

Robots need to know their location to map of their surroundings but without global positioning data they need a map to identify their surroundings and estimate their location. Simultaneous localization and mapping (SLAM) solves these dual problems at once. SLAM does not depend on any kind of infrastructure and is thus a promising localization technology for NASA planetary missions and for many terrestrial applications as well. However, state-of-the-art SLAM depends on easily-recognizable landmarks in the robot's environment, which are lacking in barren planetary surfaces. Our work will develop a technology we call MeshSLAM, which constructs robust landmarks from associations of weak features extracted from terrain. Our test results will also show that MeshSLAM applies to all environments in which NASA's rovers could someday operate: dunes, rocky plains, overhangs, cliff faces, and underground structures such as lava tubes. Another limitation of SLAM for planetary missions is its significant data-association problems. As a robot travels it must infer its motion from the sensor data it collects, which invariably suffers from drift due to random error. To correct drift, SLAM recognize when the robot has returned to a previously-visited place, which requires searching over a great deal of previously-sensed data. Computation on such a large amount of memory may be infeasible on space-relevant hardware. MeshSLAM eases these requirements. It employs topology-based map segmentation, which limits the scope of a search. Furthermore, a faster, multi-resolution search is performed over the topological graph of observations. Mesh Robotics LLC and Carnegie Mellon University have formed a partnership to commercially develop MeshSLAM. MeshSLAM technology will be available via open source, to ease its adoption by NASA. In Phase 1 of our project we will show the feasibility of MeshSLAM for NASA and commercial applications through a series of focused technical demonstrations.

## Anticipated Benefits

For the foreseeable future, robots operating beyond Earth will have to rely on triangulating rover position on a map or tracking the sun or stars. These approaches have shortcomings including limited resolution of orbital data and required interaction with ground control. SLAM is a promising means of infrastructure-free localization using local information; but unfortunately, most state-of-the-art SLAM implementations are not yet suitable for planetary exploration. Their implementations depend upon easily-recognizable landmarks that planetary environments lack. SLAM's computational complexity grows quickly with map size making it difficult to maintain kilometer-scale maps, especially on space-relevant computing hardware. MeshSLAM is significant to NASA because it provides planetary-relevant rover localization and mapping without orbital information, ground communication, or excessive computation. Furthermore in barren terrain its results will be more accurate than current methods. The partnership between Carnegie Mellon and Mesh Robotics is committed to developing and maintaining MeshSLAM following an




MeshSLAM: Robust Localization and Large-Scale Mapping in Barren Terrain, Phase II Briefing Chart Image

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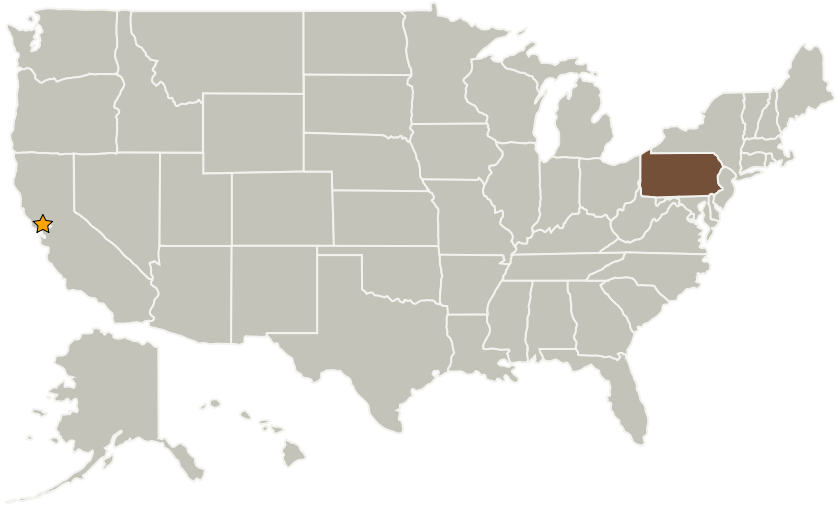
open-source philosophy. Our aim is to leverage our years of experience working with NASA research groups to mature and prepare MeshSLAM for missions of the future. MeshSLAM will add value to long-duration missions involving repeated travel, such as manned-mission pre-cursors, site preparation, and long-range mapping.

Even on Earth, accurate localization remains a challenge in frequent situations where GPS is unavailable, either temporarily (e.g., passing under bridges or operating near buildings) or permanently (e.g., indoors and underground, or when GPS is jammed). As a result, the mining, agriculture, defense, and automotive industries are investing heavily in localization technologies. Companies (e.g., Applanix, NovAtel) have seen healthy growth in the past decade by providing off-the-shelf inertial navigation systems (INSs) that fuse GPS readings with data from inertial measurement units. Unfortunately, the underlying drift of even high-quality inertial measurements is severe and thus, localization estimates diverge dramatically within minutes of a loss of GPS. MeshSLAM can complement these existing techniques and improve their accuracy in GPS-denied situations. In unmanned-vehicle applications, MeshSLAM uses data from sensors already integrated for perception, so no new equipment is required. Furthermore, MeshSLAM's efficiency makes it suitable for running on highly-integrated embedded platforms.

### Primary U.S. Work Locations and Key Partners



## Organizational Responsibility

**Responsible Mission Directorate:**

Space Technology Mission Directorate (STMD)

**Lead Center / Facility:**

Ames Research Center (ARC)

**Responsible Program:**

Small Business Innovation Research/Small Business Tech Transfer

## Project Management

**Program Director:**

Jason L Kessler

**Program Manager:**

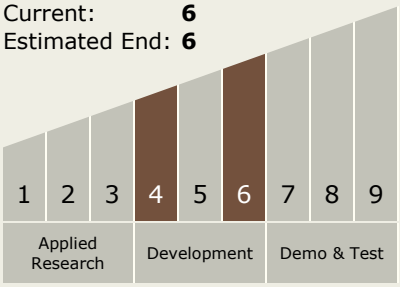
Carlos Torrez

**Principal Investigator:**

David Wettergreen

## Technology Maturity (TRL)

Start: **4**
Current: **6**
Estimated End: **6**



**Small Business Innovation Research/Small Business Tech Transfer**

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| Organizations Performing Work | Role | Type | Location |
|---|---|---|---|
| ★Ames Research Center(ARC) | Lead Organization | NASA Center | Moffett Field, California |
| Carnegie Mellon University | Supporting Organization | Academia | Pittsburgh, Pennsylvania |

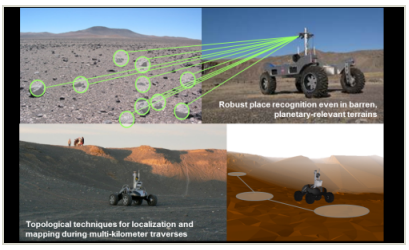
| Primary U.S. Work Locations |
|---|
| Pennsylvania |

## Project Transitions

**September 2014:** Project Start

**September 2016:** Closed out

## Images




**Briefing Chart Image**
MeshSLAM: Robust Localization and Large-Scale Mapping in Barren Terrain, Phase II Briefing Chart Image
*(https://techport.nasa.gov/image/30547)*

## Technology Areas

**Primary:**

- TX04 Robotic Systems
  - TX04.1 Sensing and Perception
    - TX04.1.3 Onboard Mapping and Data Analysis